AN INVESTIGATION OF BIORHYTHMIC INFLUENCE UPON HUMAN PERFORMANCE

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THESIS

AN INVESTIGATION OF BIORHYTHMIC
INFLUENCE UPON HUMAN PERFORMANCE

by

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September 1974

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This research attempted to define the relationship between actual performance and the state of the biorhythm. Seven subjects performed two physical tasks, one measuring gripping force and the other measuring time-on-target. Performance was compared to each of the individual biorhythm cycles and also to various combinations of the cycles. The results suggested that some functional relationship may exist. Evidence was presented supporting the concept of relativity in biorhythmic influence among individuals.

An Investigation of Biorhythmic
Influence upon Human Performance

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ABSTRACT

This research attempted to define the relationship between actual performance and the state of the biorhythm. Seven subjects performed two physical tasks, one measuring gripping force and the other measuring time-on-target. Performance was compared to each of the individual biorhythm cycles and also to various combinations of the cycles. The results suggested that some functional relationship may exist. Evidence was presented supporting the concept of relativity in biorhythmic influence among individuals.

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I. INTRODUCTION

A. BACKGROUND

There has been considerable reserarch performed in the area of cyclical rhythms in the human body. These rhythms vary from hourly to daily to monthly and even to yearly in cycle lengths. Of all these rhythms, there is a certain type which is perhaps most ingriguing to both the psychologist and the human factors engineers--the "biorhythm." It was at the turn of the century that medical scientists and psychologists acknowledged this concept of three basic cyclical rhythms beginning at birth and continuing until death. The three cyclical rhythms include the 23-day physical rhythm, the 28-day emotional rhythm, and the 33-day intellectual rhythm.

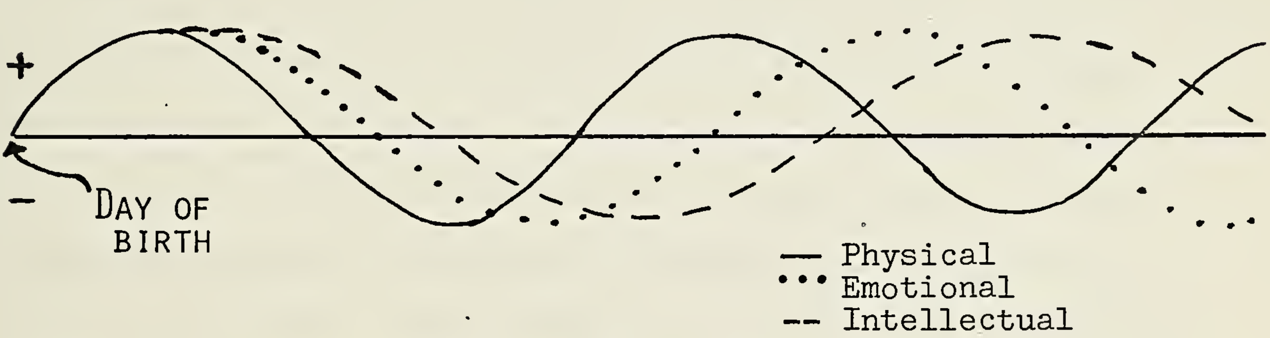

Figure 1. The Three Biorhythmic Cycles

Each of these three cycles can be thought of as a sine wave beginning its upward path at the instant of birth and continuing through the human's life. A "critical day" occurs when one of the curves is crossing the halfway point (base line) on its pass from positive to negative or from negative

to positive. A "double critical" day occurs when two curves are crossing the base line on the same day. Similarly, a "triple critical" day is one which finds three curves crossing all on the same day. Multiple-critical days are more acute in criticality than the single critical day. Of course, a triple critical day presents the greatest instability.

When in its positive portion, the curve influences the person to have a greater potential for performance than when the curve is in its lower portion. It must be understood that the positive portion of the cycle does not give an "absolute" performance level nor does it guarantee a better performance. It merely indicates that the state of the person is such as to enhance his performance to the best of his abilities, but not beyond his abilities.

Dr. Herman Swoboda, professor of psychology at the University of Vienna, is credited with much of the initial discovery and development of the 23 and 28 day cycles. In his initial research between 1897 and 1902, Swoboda investigated the periodic fluctuation of fevers and similar periodicity in illness, heart attacks, and other diseases (Thommen, 1964). He attempted to discover if this rhythmic fluctuation influenced man's feelings and actions. He published several books on the subject confirming the periodicity that produced rhythmic cycles in life.

A physician in Berlin, Dr. Wilhelm Fleiss also investigated the 23 and 28 day cycles using data obtained from his own patients. This research was carried on at the same time

as that of Swoboda, yet he was unaware. Dr. Fleiss concluded that these rhythms were "fundamental to life" and later published three books. His work was partly in collaboration with his friend Sigmund Freud.

Dr. Alfred Teltscher, in the 1920's, dealt with data from 5,000 high school and college students in Innsbruch, Austria. He found that the intellectual capability would fluctuate with a rhythmic 33-day cycle. Two other researchers, Dr. Rexford Hersey and Dr. Michael Bennet, from the University of Pennsylvania, discovered a similar 33-day cycle while studying workers' actions in railroad shops (Willis, 1972).

As the findings of these men became known, various applications and uses were explored. A Swiss engineer, Hans R. Fruch, applied biorhythm concepts to accident prevention. Alfred Judt, a German, considered the possibility of linking biorhythm to athletics. Also, several medical doctors in Switzerland and Germany applied biorhythm to the scheduling of selective surgery with astounding success.

Considerable medical evidence of biological rhythms has been provided. Among those involved in this more recent research are Fritz Went, an authority on cancer, and Dr. Franz Halberg of the University of Minnesota Medical Schools (Ward, 1971).

Most of the research on the area of biorhythms, especially the most recent work, seems to deal solely with real world data such as an accident record or a record of particularly outstanding achievements. These data bases are

certainly interesting and, obviously, lend a great deal toward validation of the biorhythm concept, but there seems to be too much tolerance for extraneous variables which could also account for some "unusual occurrence." Generally, the research appears to look at some pre-recorded data concerning uncommon occurrences in human performance and then determine whether or not such a behavior might be explained by the biorhythm. The need arises for data, obtained in such a way as to eliminate many of these "nuisance variables." Such data can be obtained in a laboratory environment in a controlled experiment.

There appears to be a need for an investigation of the actual effect of the biorhythm upon human performance over time. The question of how nearly human performance follows in its ups and downs to the ups and downs of the biorhythm curves is yet unsolved. There also seems to be some question as to the actual shape of the biorhythm curve.

B. PURPOSE

An examination of the effect of biorhythm upon physical human performance was undertaken here. This research provides a pilot study in the area of experimental performance data and the associated biorhythmic influence. The intent of this study is to give direction to later research with the goal of some day arriving at a definition of a graphical predictive function for physical performance based upon biorhythmic conditions.

Such a predictive function would permit the recognition of considerable benefits to both the military and industry. With the ability to forecast human performance capabilities long into the future, managers could greatly reduce the losses due to accidents by implementing the appropriate scheduling programs. Barring any clairvoyance or similar unexplainable foresights, this achievement has long seemed impossible. However, with our growing insights into the human biorhythm, the possibilities of such predictive powers appear conceivable.

II. THE NATURE OF THE PROBLEM

The problem investigated in this research is to determine what effect, if any, biorhythm has upon physical performance in human beings over time. In particular, this research attempts to define the relationship between actual performance and the state of the biorhythm. Of critical importance here is the correct interpretation of differing biorhythmic states. The positive portion of the biorhythm curve does not guarantee nor predict good performance. Instead, it indicates a period in which the individual's state is such as to enhance his performance. Thus it is a "potential" to perform well and not the "actual" performance which is predicted by the curve. Therefore, a major problem is encountered when one attempts to gather performance data to relate with biorhythmic conditions because one can rarely obtain data which measures "potential" in human performance. It is for this reason that man will perhaps never be able to predict human performance. He may, at best, predict only human potential or capabilities.

The approach undertaken in this study to obtain performance data is not of the ordinary nature. This study does not use someone else's data (which usually contains numerous extraneous variables) to analyze for biorhythmic influence. Rather, this study involves data gathered in a controlled laboratory environment to minimize pollution from unwanted variables. However, a problem still exists in eliminating every extraneous variable.

Before any prediction of human performance or capabilities can be achieved, an understanding of the interaction between the three biorhythm curves must be obtained. Perhaps a high positive state in the physical curve is completely nullified by a negative or critical state in the emotional or intellectual cycle. Perhaps a high state in two curves will provide no better indication of performance level than if only one curve were there. These are questions not yet fully explored in the field of biorhythmic theory.

The relativity of biorhythmic influence is a problem of utmost concern to those who wish to predict many individuals' performances. This is the question of how the biorhythm affects different people. Perhaps one individual is highly influenced by the state of the physical curve while another is influenced to a greater extent by the emotional curve. This question and each of those mentioned above, collectively form the nature of the problem to be investigated in this research.

III. EXPERIMENTAL PROCEDURE

A. EXPERIMENTAL DESIGN

The approach implemented in this research evolved around a controlled laboratory experiment. This experiment was designed to eliminate many of the extraneous, nuisance variables which tend to cloud the important factors. It consisted of two separate physical measures of human performance, each with an easily obtainable "score" or performance rating to use for day-to-day comparisons.

The first measure of performance was that of static strength in the subject's hand and arm. A Stoelting hand dynamometer was used for this task. This instrument registered in kilograms showing the amount of gripping force the subject can apply in one smooth squeeze. This device provided a definite data point for each day of observance.

The second measure of performance was that of the subject's psycho-motor ability as measured by the pursuit rotor task. The parameter used to measure the psycho-motor ability was the cumulative time that the subject was able to track and maintain contact with a moving target in a 50-second interval. This time was measured accurately in hundredths of a second.

As can be seen, the two measures employed are basically physical performance oriented. It is clear that these measures prevented distortion of true factors of performance by such things as weather conditions, machine failures, or

any number of other common nuisance variables which tend to pollute most performance data which can be obtained in a real world environment. To further eliminate unwanted variables, a section was included on the data sheet for remarks to be made by the subject concerning his state of health and rest or any other applicable comments to explain any unusual performance. To account for any learning that could have occurred in either task, an ample familiarization period was provided for each subject prior to actual evaluation.

Seven male subjects were chosen for the experiment. All were students in the Masters Degree program in Operations Research at the Naval Postgraduate School.

The time period involving the experiment was an approximate maximum of 50 days from start to finish. This arbitrary length of time was chosen so that at least two full cycles of the 23-day physical biorhythm could be observed while still permitting a timely completion of the study.

B. CONDUCT OF THE EXPERIMENT

Each subject provided for the experimenter the information needed to completely define the biorhythm. Of particular importance is the fact that throughout the course of the experiment, the state of the subject's biorhythm curve was unknown to both the experimenter and the subject. This precaution was particularly maintained for the purpose of freeing the data of one more nuisance variable. For if the subject was aware of his biorhythmic state, he might have

responded in the "prescribed" manner, even if unintentionally.

The routine of the experiment first called for the hand dynamometer task. The subject would set the hand grip on the Stoelting hand dynamometer to the prescribed setting to correctly fit his right hand. Then, while standing with his arms down at his sides, he would apply a steadily-increased gripping force until he was unable to move the dial further. For the purpose of obtaining a reliable score for this task, the subject was directed to perform this task a total of three times. After each trial, the experimenter would record the dial reading corresponding to the subject's maximum applied force. Between trials, the subject was instructed to relax his hand for a period of a least 60 seconds. The average of the three scores was computed, and this was the parameter used in the analysis.

The subject next performed the pursuit rotor tracking task. He was instructed to track and maintain contact with a target light which travelled at an irregular pace in a triangular path at 40 revolutions per minute. The subject stood in front of the console (which was at waist height in a horizontal plane) and held a photoelectric wand in his right hand. An electric timer was used to measure the cumulative amount of time that the light-sensitive wand was positioned directly over the moving light. This timer provided a specific 50-second interval for which the time-on-target was accumulating. The experimenter was able to manipulate the start switch to begin the 50-second interval.

Each subject was allowed a period of approximately 60 seconds to "warm-up." During this 60-second warm-up period, the experimenter initiated the timer without the subject's knowledge of when exactly the interval began. The purpose of this warm-up period was to bring each subject's performance up to his approximate optimal state. This was an important factor in this study since it is not "performance level" which is shown by the biorhythm but instead, the "potential" for performance. Thus, the nearer one can get to the portrayal of that potential, the nearer he can get to perfect correlation with the biorhythmic functions. At the end of the prescribed 50-second interval, the timer was automatically shut off and it displayed the amount of time for which the wand was in contact with the light. This time was recorded and used as the parameter for this psycho-motor task.

The subjects were evaluated on an irregular schedule on approximately 2.5 days out of a week for a period of an approximate maximum of 50 days.

It was necessary to observe each individual subject at one particular time of day for each day of observance. This was to elimintae possible interference from the circadian rhythms which vary through their daily cycles.

IV. ANALYSIS OF THE DATA

The subject's performance was evaluated by measuring his gripping force on the dynamometer and by measuring his total time on target (in a 50-second interval) in the pursuit rotor task. The two parameters used were kilograms and seconds, respectively. In all, there were 179 data points with approximately half from each task. There was considerable variation between the seven subjects in the scores for both tasks. Table I gives a summary of the data obtained in this experiment.

TABLE I

MEANS AND STANDARD DEVIATIONS OBTAINED ON DYNAMOMETER TASK AND TRACKING TASK BY EACH SUBJECT

	DYNAMOMETER		TRACKING TASK	
SUBJECT	MEAN	STD. DEV.	MEAN	STD. DEV.
1	39.04	4.07	16.64	2.76
2	57.43	4.59	15.28	2.85
3	48.50	3.20	23.32	4.18
4	67.69	5.69	28.30	4.32
5	49.98	3.88	22.35	5.07
6	53.43	4.40	38.09	2.68
7	50.06	2.31	31.26	6.70

Because of the nature of the data there are two basic methods of analysis presented in this study. First, the data were analyzed collectively by projecting all subjects upon the same biorhythm curve and considering performances for each day of the cycle. This was termed a frequency approach since the frequency of high and low performances was obtained.

The second basic method of analysis presented in this study considered each subject individually to determine what relationships exist between his performance and the state of his biorhythm.

A. FREQUENCY APPROACH

A plot of high and low performance frequencies was obtained for each of the three biorhythm cycles. To accomplish this, each data point for every subject was coded as being above or below the mean performance level for that subject. Then, each day of observance was translated into the day of the subject's cycle for each of the three cycles. Since all subjects' biorhythm curves were out of phase all seven subjects could have been observed on the same date while each was at a different day in his own cycle. Thus, by observing the subjects over a sampling of days, a reasonable representation of the collective performance trends could be seen when all subjects were projected onto the same biorhythm cycle. Figures 2 and 3 display the histograms showing the frequencies of above and below average performances for each of the three cycles. This procedure was completed for both the dynamometer task and the pursuit rotor task.

It seems logical to say that a larger proportion of above-mean performances should occur in the first half of the cycle while a larger proportion of below-mean performances occur in the last cycle if that cycle was at all

DYNAMOMETER TASK

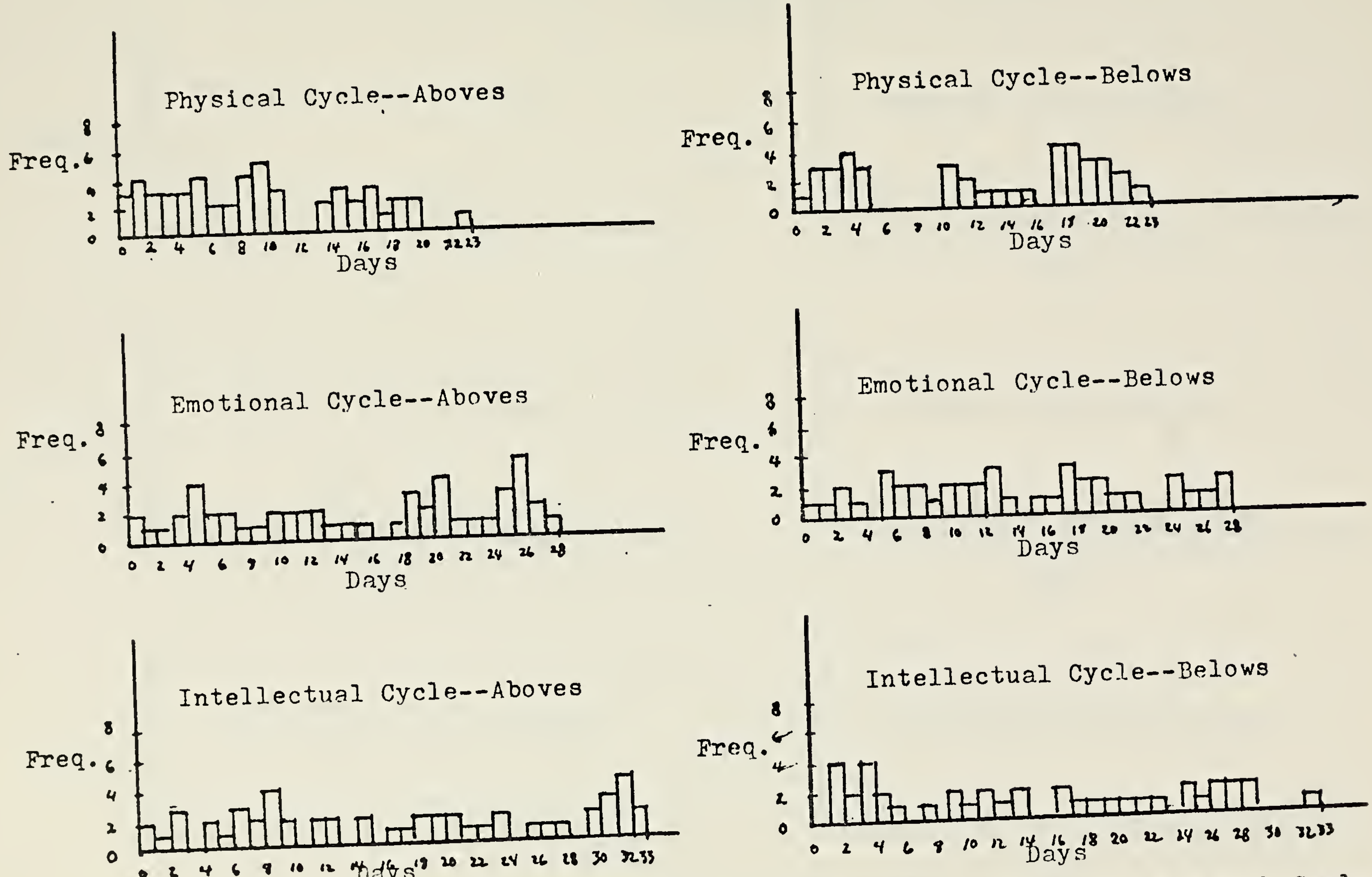

Figure 2. Frequency Plots of Above and Below-mean Performance for Each Cycle

TRACKING TASK

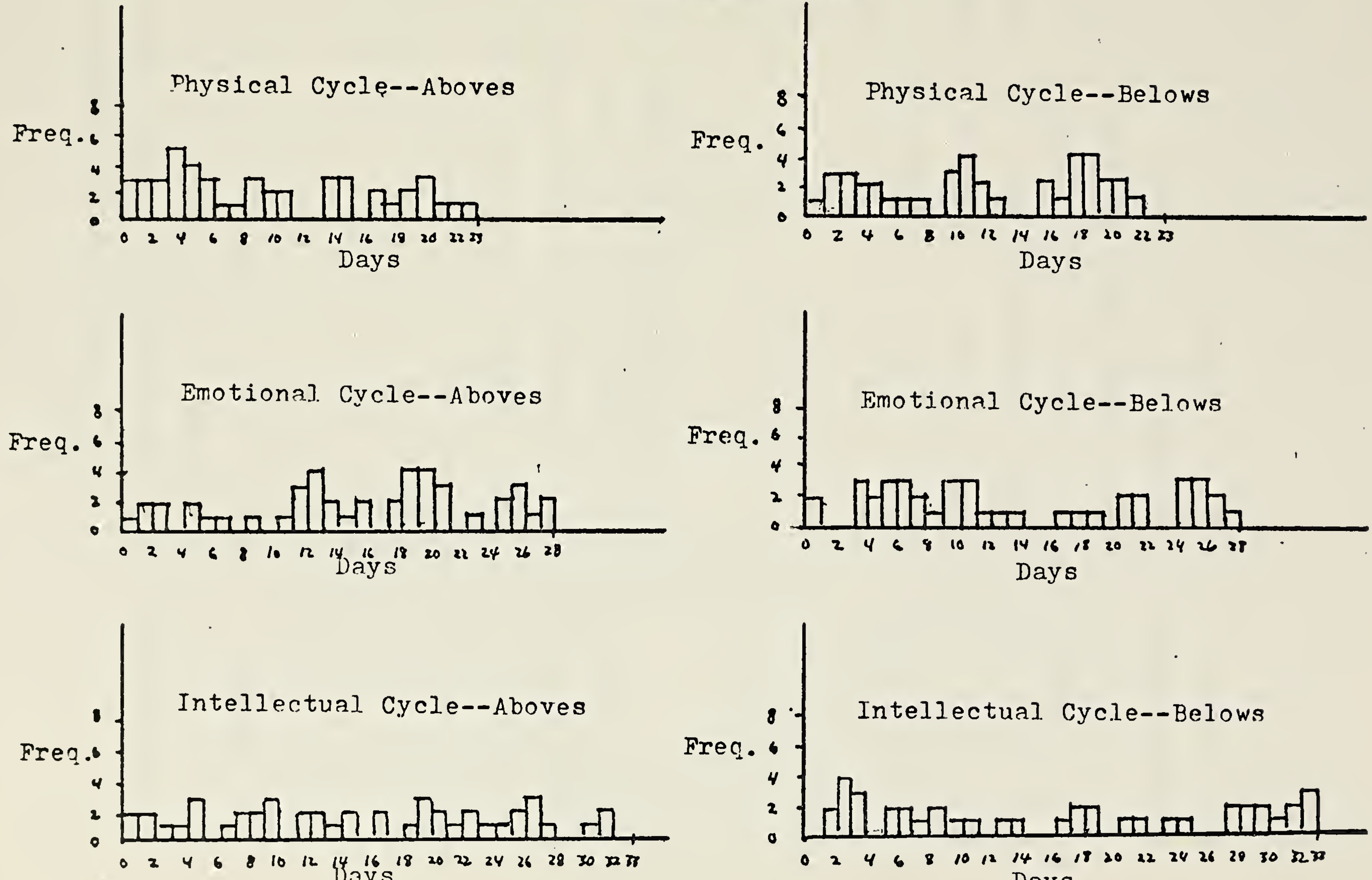

Figure 3. Frequency Plots of Above and Below-mean Performance for Each Cycle

related to performance. By a casual inspection of the physical (23-day) cycle for the dynamometer task shown in Figure 2, a noticeable skewing of the data can be seen. This could be expected since the dynamometer task is a particularly "physical" task. As expected, the other two curves do not appear to have as much influence for this muscular task.

The frequency plots for the tracking task shown in Figure 3 show similar trends to those in Figure 2. An interesting effect seems to occur with the emotional cycle as the above-mean performances appear to be more highly concentrated toward the last half of the cycle. This is perhaps contrary to one's intuition. The possibility exists that some form of interaction between curves may be occurring to affect the plot for the emotional cycle in this manner.

1. Tests for Functional Relationships

The first step in analyzing this data was to determine whether or not the above-mean and below-mean performances were distributed uniformly over each of the three cycles. In the event that for each cycle both high and low performances were uniformly distributed, one would be led to conclude that no influence due to biorhythmic state was present. However, if even for one of the three biorhythmic cycles the null hypothesis of uniformity was rejected, the deduction would be that performances followed some specific functional form. The next step would be to determine just what functional form that would be.

The Kolmogorov-Smirnov one-sample test was chosen to test for uniformity. This test determines whether the scores in the sample can reasonably be thought to have come from a population having the uniform distribution. The null hypothesis was, therefore, that the above-mean and below-mean performances were distributed uniformly for each of the three biorhythmic cycles. Table II contains the results of these tests.

TABLE II

RESULTS OF KOLMOGOROV-SMIRNOV ONE-SAMPLE TESTS FOR UNIFORMITY

	CYCLE	ABOVE-MEAN/ BELOW-MEAN	STATISTIC (D)	SIGNIFICANCE LEVEL
Dynamometer Task	Physical	A	D=.214	$.05 > P > .01$
		B	D=.164	$P \approx .21$
	Emotional	A	D=.094	$P > .20$
		B	D=.086	$P > .20$
	Intellectual	A	D=.091	$P > .20$
		B	D=.148	$P > .20$
Tracking Task	Physical	A	D=.187	$.10 > P > .05$
		B	D=.064	$P > .20$
	Emotional	A	D=.154	$P \approx .21$
		B	D=.144	$P > .20$
	Intellectual	A	D=.095	$P > .20$
		B	D=.117	$P > .20$

(All sample sizes greater than 35)

At the .10-level of significance the null hypothesis can be rejected in the cases of above-mean performances over the physical cycle for both tasks. The conclusion is because these scores are not distributed uniformly, there exists some

other distribution which underlies high performance. It should be noticed that the below-mean scores for the physical cycle for both tasks were not significant ($P>.20$) to any great degree. Perhaps this finding indicates that a certain amount of over-compensation occurs when the subject feels "less capable" during the last half of his cycle, tending to even out the distribution of below-mean performances.

In a study by Redgrove (1968) a similar phenomenon was recorded as output increased at the point of the menstrual cycle which, intuitively, should have had decreased performance (Colquhoun, 1971). The possibility yet remains that phases of the cycle have different effects on different types of tasks, a statement verified by Vernon and Parry (1949).

When considering the other cases which proved to be insignificant ($P>.20$), one must conclude that either the other biorhythmic cycles had no significant effect or that any effect present was masked by combinatory effects between cycles and other noise in the system.

The next test for functional relationships between high and low performances was the chi-square test for two independent samples. This contingency test was chosen to test the null hypothesis that the above-mean and below-mean performances do not differ with respect to any characteristic and, therefore, with which scores fall into several categories. This was just another test to aid in determining what functional form was driving the data.

TABLE III

RESULTS OF CHI-SQUARE CONTINGENCY TESTS BETWEEN ABOVE-MEAN AND BELOW-MEAN PERFORMANCES FOR EACH CURVE AND BOTH TASKS

	CYCLE	CHI-SQUARE VALUE	DEGREES OF FREEDOM	SIGNIFICANCE LEVEL
Dynamometer Task	Physical	11.88	6	.05>P>.01
	Emotional	4.63	6	P>.50
	Intellectual	7.17	6	.40>P>.30
Tracking Task	Physical	6.06	6	.50>P>.40
	Emotional	11.59	6	.10>P>.05
	Intellectual	10.72	6	.10>P>.05

Interestingly, the data from the dynamometer task under the physical cycle was again significant at the .10 significance level. This meant that not only were the high and low performances not distributed uniformly, but they were also distributed differently. That is, two separate functional forms appear to be present under the physical cycle, one for above-mean performances and one for below-mean performances.

The results of the emotional and intellectual cycles for the pursuit rotor tracking task were also significant at the .10 significance level, allowing the rejection of the null hypothesis. This says that the distributions of high and low performances differ with respect to some characteristic for both the emotional and intellectual cycles. An explanation involves the fact that the pursuit rotor tracking

task displays more than just physical skills, it is a psychomotor task. Thus, the emotional and intellectual cycles should expectedly show some influence here.

2. Modifications of Data Groupings

Many questions have arisen in the area of exactness in cycle length in biorhythmic cycles. Some say precision is lacking in the cyclic repetitions of the three curves. The basis for the criticism lies in the concept of a "built-in" biorhythm variance. Willis (1972) referred to such a variance when he defined a critical day or "critical category" as that period of time which includes the day, and a 10-hour period either side of the day on which the curve crosses the base line. One problem is the general uncertainty in one's exact time of birth. Two persons may have been born on the same day while still having almost 24 hours of age difference.

In a study cited from Colquhoun, Biological Rhythms and Human Performance, 1971, it was found that the female menstrual cycle was not of any fixed length. The mean is approximately 28 days with a normal range of difference at ± 6 days (Redgrove, 1968). There exists a striking resemblance between the female menstrual cycle and the 28-day emotional rhythm. Perhaps a similar variance in range can be found in the biorhythm cycle.

Because of the obvious and well-known reasons for a built-in variance in the biorhythm cycles, a shift of a full 24 hours in either direction would still be acceptable. Such a shift was applied to the performance data obtained

in this experiment to obtain what was called the "optimal shift." Some data points were shifted either one day ahead or one day back in the cycle to provide an overall effect of possible extreme non-uniformity. The same two tests for functional relationships were run again under these new conditions. In each test type the null hypotheses were the same as stated before. Tables IV and V contain the results of these tests.

TABLE IV

RESULTS OF KOLMOGOROV-SMIRNOV ONE-SAMPLE TESTS FOR UNIFORMITY - MODIFIED DATA

	CYCLE	ABOVE-MEAN/ BELOW-MEAN	STATISTIC (D)	SIGNIFICANCE LEVEL
Dynamometer Task	Physical	A	D=.263	P<.01
		B	D=.208	.10>P>.05
	Emotional	A	D=.169	P=.10
		B	D=.107	P>.20
	Intellectual	A	D=.189	P=.05
		B	D=.152	P>.20
Tracking Task	Physical	A	D=.230	.05>P>.01
		B	D=.133	P>.20
	Emotional	A	D=.146	P>.20
		B	D=.161	P>.20
	Intellectual	A	D=.117	P>.20
		B	D=.215	.05>P>.01

(All sample sizes greater than 35)

The results from this regrouping of the data were definitely of greater significance. At the .10 level of significance, the null hypothesis of no difference between

TABLE V

RESULTS OF CHI-SQUARE CONTINGENCY TESTS BETWEEN ABOVE-MEAN AND BELOW-MEAN PERFORMANCES FOR EACH CURVE AND BOTH TASKS MODIFIED DATA

	CYCLE	CHI-SQUARE VALUE	DEGREES OF FREEDOM	SIGNIFICANCE LEVEL
Dynamometer Task	Physical	33.95	6	$P<.001$
	Emotional	12.90	6	$.05>P>.02$
	Intellectual	26.27	6	$P<.001$
Tracking Task	Physical	18.09	6	$.01>P>.001$
	Emotional	22.89	6	$P<.001$
	Intellectual	10.72	6	$.10>P>.05$

frequency distribution of above and below-mean performance levels was rejected for all cases. At the same level of significance, many of the samples of high and low performances can be viewed as non-uniformly distributed. This portion of the analysis serves as an example of the great variance incorporated in the biorhythm function, and it displays some of the problems associated with gathering experimental data. The elimination of a greater portion of this variance will be a giant step toward arriving at a universal predictive function for physical performance based upon biorhythmic conditions.

The purpose of this modification in the data was only to point out the possible variance in the biorhythmic functions. It must be clearly understood that this "modified" data was not used further in this analysis, and any results

found later in this study were based upon the data as originally recorded. However, the reader must consider this variance as a possible means of lending even greater significance to the findings yet to be shown herein.

B. RELATIONSHIPS BETWEEN INDIVIDUAL PERFORMANCE AND BIORHYTHM

The actual performance scores for each subject was plotted against each of his three biorhythm cycles. The correlation (r) was determined for each curve through the Biomed-02R Stepwise Regression computer program. This particular program was used because it offered a sinousoidal transgeneration permitting a plot of the biorhythm curves. The results for all subjects in both tasks are shown in Table VI.

TABLE VI

CORRELATIONS OF PERFORMANCE WITH BIORHYTHM CURVES FOR EACH SUBJECT IN BOTH TASKS

SUBJECT	DYNAMOMETER			TRACKING TASK		
	P	E	I	P	E	I
1	.040	.051	-.634	.285	-.684	-.302
2	-.386	.237	.043	-.518	.422	-.234
3	.459	.443	-.362	.207	.465	-.595
4	.325	-.199	.238	.716	-.707	.694
5	-.082	-.342	.385	.282	-.509	-.161
6	-.044	.290	-.006	-.004	-.099	-.250
7	.367	-.354	.047	.170	-.385	.011

Considerable variation in correlations can be seen from these results. For some subjects a relatively high level of

correlation is seen between performance and the state of one of the cycles, while for others very little or even negative correlations are found. Because of the lack of some obvious trend in high correlation with any particular curve, one must deduce that either no biorhythmic effect exists or some combination between biorhythmic cycles (or some other unseen factor) is driving the results. At any rate, since some subjects show high correlations while others show low correlations, support is given to the concept of individual differences in biorhythmic influence and sensitivity. That is, there appears to be some factor of relativity involved with biorhythm influence.

To further investigate the idea of a possible underlying effect of some combination of the three cycles a multiple regression was performed. The dependent variable, the performance score, was expressed as a function of the three cycles. For each subject a regression equation was found along with its multiple regression correlation coefficient (mult. r). The results from both tasks are presented in Table VII.

Several high correlations are found under multiple r, but the regression equations vary in their coefficients for the three biorhythm curves. Though it appears that some functional relationship exists, it does not seem safe to say just what that function is.

To obtain some gist of the collective effects from all seven subjects, the computer program was used again, but

TABLE VII

REGRESSION EQUATIONS AND MULTIPLE CORRELATION COEFFICIENTS (MULT. r) FROM PERFORMANCE REGRESSED WITH THREE BIORHYTHM CYCLES

Dynamometer

Subject	Equation	Mult. r
1	37.85 + 2.62P + 0.48E - 5.25I	.769
2	57.79 - 6.56P - 6.46E + 3.10I	.450
3	49.47 + 2.90P + 1.37E - 2.88I	.839
4	64.87 +15.73P +38.85E +30.10I	.746
5	50.10 - 2.14P - 3.79E + 0.55I	.525
6	53.30 - 0.66P + 2.92E - 1.49I	.368
7	50.04 + 0.94P - 0.52E - 0.72	.411

Tracking Task

Subject	Equation	Mult. r
1	17.23 + 2.71P - 2.76E - 2.06I	.940
2	16.20 + 3.83P +10.20E - 5.96I	.829
3	24.69 + 2.86P + 1.83E - 4.58I	.852
4	27.52 + 6.49P +11.64E +11.08I	.803
5	22.10 - 3.22P - 8.44E - 3.76I	.677
6	38.41 + 0.43P + 0.00E - 1.19I	.271
7	31.62 - 7.60P -10.34E - 2.14I	.588

this time, with all the data points. The data points had to be scaled into a value of "percentage difference from the mean." For each subject, the mean performance score was found. Then, from each observation, the mean was subtracted and the total (either positive, zero, or negative) was divided by the mean. The resulting values ranged from positive to negative, of course. These values formed a ratio scale, permitting calculations of the type necessary

to determine the correlations between the performance scores and the status of the biorhythm curves for both tasks. The regression equation and multiple correlation coefficient for both tasks were also determined. The results are presented in Table VIII.

TABLE VIII

CORRELATIONS AND MULTIPLE REGRESSION RESULTS FROM REGRESSION OF ALL SUBJECTS' PERFORMANCE WITH BIORHYTHM CYCLES FOR BOTH TASKS

	Mean	Std. Dev.	Correlations P	E	I
Dynamometer Task	0.0315	7.32	.087	-.008	.003
Tracking Task	0.0023	16.92	.191	-.275	-.060

	Regression Equation	Mult. r
Dynamometer Task	-0.00689 + 1.08P + 0.299E - .2896I	.095
Tracking Task	0.11673 + 3.515P - 5.827E - 3.888I	.327

To further investigate the effect of combining biorhythm curves, a simple graphical addition of the curves was obtained to test the possibility of such a relationship. Three particular combinations were of interest: (1) physical and emotional curves, (2) physical and intellectual curves, and (3) physical, emotional, and intellectual curves. Notice that the physical curve is present in each combination since the two tasks involved in this study were of a physical nature.

Thommen (1964) dealt with this combination of cycles when he considered error and accidents. He found that some curve combinations are more conducive to error and accidents than others. "For example, a high emotional curve in the positive state, at the same time an intellectual and physical curve are in the low or negative state, often precipitated accidents." (Willis, 1972) Similar results were found by Ault and Kinkade (1972).

By simply adding curves in this purely graphical method, an assumption of equal influence was actually being made. That is to say, that all amplitudes were originally considered equal. The common theory of biorhythms states very little about the meaning of curve amplitudes. However, if for some individual, one of the three cycles seemed most influential, perhaps this curve should be assigned a higher amplitude than the other two before the graphical addition was made. This would be in effect a weighting function for influence upon a specific individual. Because no such weighting was made here, the reader is free to speculate about the probable increase in significance which may have been gained by such a measure.

The correlations were obtained for these new biorhythmic functions by the same methods described above. The results are presented in Table IX.

A wide variation in correlations was found, supporting again the concept of the relativity of biorhythmic influence between individuals. Although this very basic combination

TABLE IX

CORRELATIONS OF PERFORMANCE WITH COMBINATIONS OF BIORHYTHM CURVES FOR EACH SUBJECT IN BOTH TASKS

	Dynamometer			Tracking Task		
Subject	P+E	P+I	P+E+I	P+E	P+I	P+E+I
1	.056	-.328	-.235	-.230	-.001	-.292
2	-.300	-.253	-.099	-.268	-.553	-.268
3	.612	.085	.266	.428	-.198	.010
4	.214	.303	.417	-.050	.757	.780
5	-.442	.247	.049	-.141	.098	-.333
6	.146	-.032	.101	-.061	-.148	-.146
7	-.060	.246	.015	-.527	.105	-.243

of curves seemed not to show a definite universal function for a biorhythmic predictor of physical performance, one must acknowledge that an infinite number of possibilities yet remain. A discussion of some of these possible functional forms and various problems clouding the whole issue are presented in the conclusion.

V. CONCLUSION

The human being is subjected to and regulated by a multitude of cycles. Researcher Arne Sollenberger in his book Biological Rhythm Research, cites various frequency rangings including "nervous transmissions and fibrillar musculature" at approximately 2000 cycles per second (Wallerstein and Roberts, 1973). Yet other research has determined cycles which range from ten seconds to several days. With such variance between and fluctuation within these physiological entities, man's responses and perhaps his performance levels are found to vary. As men learn more about this awesome cycle pyle which affects their every minute, they may some day arrive at a workable predictive function for human performance potential.

This research provides just another step in the long pathway toward understanding how performance is effected by these many cycles. The area of determining how nearly human performance follows with the biorhythm curves is a relatively untrod field. Little research is done in this area because of the many difficulties encountered when attempting such an endeavor. The major problem centers around the idea that biorhythms can indicate only "potential" for performance and not the actual level of performance. The fact is when an individual's biorhythm indicates that he is at a peak in his potential, an innumerable sum of extraneous variables could overshadow this fact, leading to decreased performance.

Another basic problem involves the wide variance inherent in the cycle day definition. The ever-present concept of learning tends to cloud the issue in an experiment such as this. To have better eliminated this variable in this study, a longer period of observation could have been used.

Evidence was presented supporting the concept of the relativity of biorhythm influence among individuals. This evidence was in the form of a wide spread in the correlations between performance and the curves for the different subjects. Regression equations were developed using performance as the dependent variable and cycles as the independent variables. The multiple correlation coefficients were generally significant, showing that performance can be expressed as a function of the biorhythmic cycles. Recognizing that the coefficients in the regression equation were not the same for each subject, these results cannot be claimed as a universal function for performance. This again points to the concept of individual differences in biorhythmic influence.

Various combinations of biorhythm curves were graphically added in an attempt to uncover any interrelations between curves and the associated effect upon performance. Though the results indicated generally low correlations with performance, the author felt that further research in this field could prove fruitful.

The question of curve shape has been addressed in this study. Though this research employed the customary sine wave form of the biorhythm cycle, several distinctly different

possibilities may exist. Perhaps the curve takes the form of a step function with a higher value in the first half of the cycle and a lower value in the second half. Then again, the curve may best be described as some form of a Beta or Gamma function. Other possibilities include a "skewed sine" function with extreme highs and lows near the cross-over point from positive to negative. These various untested hypotheses are few among the many reasonable alternatives. They deserve further research as does the entire area of cyclical rhythms in the human being.

To develop a workable predictive function for performance a study is needed of the length adequate to expose the numerous extraneous variables, statistically sound enough to uncover any hidden interactions, and designed with such ingenuity as to provide for the measurement of "potential" instead of "actual" performance. Only after such research is produced will this worthy goal be attained.

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